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(54) Title of the invention: SUBSTRATE PROCESSING METHOD AND DEVICE THEREOF

(57) Abstract

Purpose: To provide a substrate processing method and device which can achieve high yield and contribute to an improvement in a processing accuracy and a decrease of defects of a substrate by solving the problem of air-bubble generation and the problem of a difference in processing time depending on the position in the surface of a processing substrate.

Configuration: In a single substrate processing technique, a nozzle 7 is provided with a nozzle ejection port arrangement face 9 corresponding to a processing area 2, and a processing liquid film 3 is formed on this area by using surface tension and then is

brought into contact with the surface of the processing area 2 from the upper side. In addition, a processing liquid is supplied to the processing area 2 in a state in which a relative interval between the surface of the processing area 2 and the surface of the nozzle ejection port arrangement face 9 is continuously changed. In addition, by making the vicinity of nozzle holes 8 to be in a negative pressure state, a processing liquid is supplied to the processing area 2.

6: VERTICAL DRIVING MECHANISM
10: DEVELOPER
15: END POINT DETERMINATION MECHANISM
16: DEVELOPER QUANTITY CONTROL MECHANISM
18: INERT GAS GENERATING MECHANISM
E PORTION

Scope of Patent Claims

Claim 1

A substrate processing method of performing liquid processing by arranging a nozzle over a processing substrate so as to be opposed thereto and supplying a processing liquid to a desired processing area in the processing substrate from nozzle holes of the nozzle, the nozzle having a plurality of the nozzle holes and nozzle ejection ports which are ejection ports of the nozzle holes, the nozzle ejection ports being arranged on an arrangement face, the method comprising the steps of:

forming a processing liquid film of the processing liquid by supplying the processing liquid to the surface of the nozzle and by surface tension; and

processing the substrate by bringing the surface of the processing area into contact with the processing liquid film after the processing liquid film-forming step.

Claim 2

A substrate processing method of performing liquid processing by arranging a nozzle over a processing substrate so as to be opposed thereto and supplying a processing liquid to a desired processing area in the processing substrate from nozzle holes of the nozzle, the nozzle having a plurality of the nozzle holes and nozzle ejection ports which are ejection ports of the nozzle holes, the nozzle ejection ports being arranged on an arrangement face, the method comprising the step of:

processing the substrate by arranging the plurality of nozzle holes and the surface of the processing substrate so as to be opposed to each other with a continuous change in a relative interval therebetween and supplying the processing liquid from the plurality of nozzle holes at different times.

Claim 3

The substrate processing method according to Claim 2,

wherein the processing is performed by forming the processing liquid film in advance on the arrangement face by surface tension and bringing the surface of the processing area into contact with the processing liquid film.

Claim 4

A substrate processing method of performing liquid processing by arranging a nozzle over a processing substrate so as to be opposed thereto and supplying a processing liquid to a desired processing area in the processing substrate from nozzle holes of the nozzle, the nozzle having a plurality of the nozzle holes and nozzle ejection ports which are ejection ports of the nozzle holes, the nozzle ejection ports being arranged on an arrangement face, the method comprising the step of:

supplying the processing liquid by making a space as a closed space, in which the processing substrate and the nozzle arrangement face are opposed to each other, to be in a negative pressure state.

Claim 5

The substrate processing method according to Claim 4, further comprising the steps of:

forming a processing liquid film in advance by surface tension on the arrangement face by supplying the processing liquid from the nozzle holes with a negative pressure; and

processing the substrate by bringing the surface of the processing area into contact with the processing liquid film.

Claim 6

The substrate processing method according to any one of Claims 1, 3 and 5,

wherein in the liquid film-forming step, the end point of a film thickness is determined by measuring the film thickness of the processing liquid film.

Claim 7

A substrate processing device comprising:

a processing liquid supply mechanism for supplying a processing liquid to a processing substrate; and

a substrate holding portion for holding the processing substrate,

wherein the processing liquid supply mechanism includes a plurality of nozzle holes which have nozzle ejection ports and are arranged over the processing area, a nozzle ejection port arrangement face which forms a continuous plane between the plurality of ejection ports and is arranged so as to be opposed to an area having a projection area substantially corresponding to the processing area, and a processing liquid supply stopping mechanism which stops the supply of the processing liquid at the stage of a desired supply quantity when the processing liquid is supplied so as to form a processing liquid film on the nozzle ejection port arrangement face.

Claim 8

A substrate processing device comprising:

a processing liquid supply mechanism for supplying a processing liquid to a processing substrate; and

a substrate holding portion for holding the processing substrate,

wherein the processing liquid supply mechanism has a plurality of nozzle holes which have nozzle ejection ports and are arranged over the processing area and means for continuously differentiating relative intervals between the nozzle ejection ports of the plurality of nozzle holes and the surface of the processing substrate.

Claim 9

The substrate processing device according to Claim 8,

wherein the processing liquid supply mechanism includes a nozzle ejection port arrangement face communicating the plurality of nozzle ejection ports with each other.

Claim 10

The substrate processing device according to Claim 9,

wherein the nozzle ejection port arrangement face is shaped such that the surface position thereof continuously rises from the center to the peripheral portion along the vertical cross section.

Claim 11

The substrate processing device according to Claim 10,

wherein the arrangement face is rotationally symmetrical with respect to the vertical axis at the center.

Claim 12

The substrate processing device according to Claim 9,

wherein the nozzle ejection port arrangement face can be tilted relatively to the processing substrate.

Claim 13

A substrate processing device comprising:

a processing liquid supply mechanism for supplying a processing liquid to a processing substrate; and

a substrate holding portion for holding the processing substrate,

wherein the processing liquid supply mechanism includes a plurality of nozzle holes which have nozzle ejection ports and are arranged over the processing area, a fence which forms a closed space including at least the processing liquid supply mechanism in processing the processing substrate, a suction pump which is connected to a part of the closed space and makes the closed space to be in a negative pressure state and negative pressure release means for releasing the negative pressure state of the closed space, and the plurality of nozzle ejection ports are arranged so as to be opposed to an area having a projection area substantially corresponding to the processing area.

Claim 14

The substrate processing device according to Claim 13,

wherein the processing liquid supply mechanism includes a nozzle ejection port arrangement face which forms a continuous plane between the plurality of ejection ports so as to form a processing liquid film.

Claim 15

The substrate processing device according to any one of Claims 7 to 14,

wherein the plurality of nozzle holes are arranged such that the density thereof is higher in the peripheral portion than in the center portion of the arrangement face.

Claim 16

The substrate processing device according to any one of Claims 7 to 14,

wherein the processing liquid stopping mechanism includes a film thickness monitor for monitoring a film thickness of the processing liquid film formed on the nozzle ejection port arrangement face and an end point determination mechanism for determining an end point based on the result of the monitor.

Detailed Description of the Invention

[0001]

Industrial Field of Utilization

The present invention relates to a method and device for processing a processing substrate by supplying a processing liquid, and relates to techniques suitable for developing, washing, etching and the like which are applied to semiconductor wafers, reticles, glass substrates for a liquid crystal display (LCD), glass substrates for an optical disk and the like.

[0002]

Prior Art

For example, in a semiconductor manufacturing process, a fine device pattern is formed on a semiconductor wafer (hereinafter, referred to as wafer) which is a processing substrate. The pattern is formed by the following processes. That is, a photosensitive resin film is applied to a base film to be processed on a wafer, a pattern formed on a reticle is selectively exposed in a desired area in the photosensitive resin film, and if necessary, post-exposure baking (PEB) is performed to form a latent image. Then, in a developing device, by supplying a developer (organic compound or alkaline aqueous solution), developing and rinsing are carried out and the unnecessary resist of the exposed portion or the non-exposed portion is dissolved and removed, and thus a resist image is selectively formed and then a drying process is performed. After that, the base film is subjected to etching by employing the resist as a mask and the pattern is formed.

[0003]

Next, characteristics of developing methods will be described. In single substrate spray developing or paddle developing, not only is damage caused due to the collision of a developer ejected from a nozzle with a resist, but also a pattern defect or a localized change in dimensions is caused due to bubbles which are generated when air is taken in or collision occurs during the ejection. In addition, since a developer requires a diffusion time for running through the entire surface of a wafer, a developing time is substantially different depending on the position in the wafer surface and thus a variation is caused in

resist dimensions in the surface. This leads to a decrease in the in-plane uniformity of finished dimensions after etching. These problems, along with an increase in a wafer diameter, have a large influence. In addition, since most of the ejected developer drops out of a wafer while in an unreacted state, the developer is wastefully consumed. Accordingly, various techniques for solving the problems such as the shock at the time of collision of a developer and the wasteful consumption of a developer have been developed in various single substrate developing methods.

[0004]

As a developing method which is currently used in production lines, there is a developer supply method in which, as shown in FIGS. 9 (sectional view) and 10 (top view), a rod-like nozzle having a dense number of holes and a wafer are arranged so as to be close to and opposed to each other and a developer is supplied from the upper rod-like nozzle while the wafer is rotated.

[0005]

In JP-A-7-235473, there is disclosed a method and device for reducing a diffusion time by rapidly diffusing a developer by using a capillary phenomenon in a clearance between a substrate to be developed and a substrate which is made to be close to the substrate to be developed.

[0006]

Problems to be Solved by the Invention

However, according to the above-described technique, the problems of the shock at the time of collision of a processing liquid (developer) and the developer consumption quantity can be solved, but the problem of air-bubble generation and the problem of a difference in processing (developing) time depending on the position in the wafer surface cannot be solved.

[0007]

That is, in the developing method of FIG. 9, since a developer is supplied to the clearance between a resist 2 and a plurality of nozzle holes 8 which are adjacent to each other as shown in FIG. 11 (enlarged sectional view of the D portion of FIG. 9), air is introduced between the resist 2 and a developer film 3 to be formed, and thus fine air-bubbles 32 are generated. Most of the fine air-bubbles 32 in the liquid are left and remain even when a wafer 1 rotates. As a result, a number of fine air-bubbles 32 are included in the developer layer in the course of the developing which proceeds as shown in FIG. 12, and due to the fine air-bubbles 32, a pattern defect or a localized change in dimensions is caused when etching is completed. Moreover, since a developer runs through the entire wafer surface at the stage of half-cycle rotation of the wafer, the problem of a difference

in developing time depending on the position in the wafer surface also cannot be completely solved.

[0008]

In JP-A-7-235473, when a developer is diffused in a horizontal direction due to a capillary phenomenon, it is difficult to ensure that the developer spreads at a constant speed in a 360-degree direction toward the peripheral portion from the center and localized wet portions (air trapping) are caused. Accordingly, air-bubbles 19 are generated. One reason thereof is that the in-plane distribution of wettability is not completely uniform, and particularly, in the case of the resist, a difference occurs in wettability of a developer between an exposed portion and a non-exposed portion. The air-bubbles 19 have an adverse influence as in the case of the air-bubbles of FIG. 12. In addition, since a developer is supplied to the peripheral portion from the center due to a capillary phenomenon, a longer diffusion time is required, and as in the method of FIG. 9, the problem of a difference in developing time depending on the position in the wafer surface cannot be completely solved.

[0009]

With the above-described technique, the problems of the shock at the time of collision of a developer and the developer consumption quantity can be solved, but the technique cannot be a means for solving the problem of a large amount of air-bubbles included in the liquid during developing and the problem of a difference in developing time depending on the position in the wafer surface, which is caused due to the generation of a difference in developing start time.

[0010]

The present invention provides a substrate processing method and device which can achieve high yield and contribute to an improvement in the accuracy of processing (developing) and a decrease of defects of a substrate by significantly reducing the number of air-bubbles in the processing liquid and supplying the processing liquid without delay.

[0011]

<u>Means to Solve Problems</u>

In order to achieve the above-described object, the gist of the typical main portion of a substrate processing method and device according to the present invention is to provide a method and device for processing a substrate in a manner such that a processing liquid is supplied to an arrangement face of a plurality of nozzle holes, a processing film is formed on an area substantially corresponding to a processing area by using surface tension and then the surface of the processing liquid film is brought into contact with the surface of the processing area from the upper side.

[0012]

That is, according to a substrate processing method described in Claim 1, a substrate processing method of performing liquid processing by arranging a nozzle over a processing substrate so as to be opposed thereto and supplying a processing liquid to a desired processing area in the processing substrate from nozzle holes of the nozzle, in which the nozzle has a plurality of the nozzle holes and nozzle ejection ports which are ejection ports of the nozzle holes, and the nozzle ejection ports are arranged on an arrangement face, includes the the steps of: forming a processing liquid film of the processing liquid by supplying the processing liquid to the surface of the nozzle and by surface tension; and processing the substrate by bringing the surface of the processing area into contact with the processing liquid film after the processing liquid film-forming step are included. According to a substrate processing device described in Claim 7, in a substrate processing device including: a processing liquid supply mechanism for supplying a processing liquid to a processing substrate; and a substrate holding portion for holding the processing substrate, the processing liquid supply mechanism includes a plurality of nozzle holes which have nozzle ejection ports and are arranged over the processing area, a nozzle ejection port arrangement face which forms a continuous plane between the plurality of ejection ports and is arranged so as to be opposed to an area having a projection area substantially corresponding to the processing area, and a processing liquid supply stopping mechanism which stops the supply of the processing liquid at the stage of a desired supply quantity when the processing liquid is supplied so as to form a processing liquid film on the nozzle ejection port arrangement face.

[0013]

In addition, in order to achieve the above-described object, there are provided a method and device for processing a substrate in a manner such that a plurality of nozzle holes are arranged so as to be opposed to an area having a projection area substantially corresponding to the processing area by continuously changing a relative interval with the surface of the processing substrate and the processing liquid is supplied from the plurality of nozzle holes at different times.

[0014]

That is, according to a substrate processing method described in Claim 2, in a substrate processing method of performing liquid processing by arranging a nozzle over a processing substrate so as to be opposed thereto and supplying a processing liquid to a desired processing area in the processing substrate from nozzle holes of the nozzle, the nozzle has a plurality of nozzle holes and nozzle ejection ports which are ejection ports of the nozzle holes, the nozzle ejection ports are arranged on an arrangement face, and the step of: processing the substrate by arranging the plurality of nozzle holes and the surface of the processing substrate so as to be opposed to each other with a continuous change in

a relative interval therebetween and supplying the processing liquid from the plurality of nozzle holes at different times is included. According to a substrate processing device described in Claim 8, in a substrate processing device including: a processing liquid supply mechanism for supplying a processing liquid to a processing substrate; and a substrate holding portion for holding the processing substrate, the processing liquid supply mechanism has a plurality of nozzle holes which have nozzle ejection ports and are arranged over the processing area and means for continuously differentiating relative intervals between the nozzle ejection ports of the plurality of nozzle holes and the surface of the processing substrate.

[0015]

In addition, in order to achieve the above-described object, there are provided a method and device for processing a substrate in a manner such that the processing liquid is supplied by making a closed space, which covers a plurality of nozzle holes arranged in an area having a projection area substantially corresponding to the processing area, to be in a negative pressure state.

[0016]

That is, according to a substrate processing method described in Claim 4, a substrate processing method of performing liquid processing by arranging a nozzle over a processing substrate so as to be opposed thereto and supplying a processing liquid to a desired processing area in the processing substrate from nozzle holes of the nozzle, in which the nozzle has a plurality of nozzle holes and nozzle ejection ports which are ejection ports of the nozzle holes, and the nozzle ejection ports are arranged on an arrangement face, includes the step of: supplying the processing liquid by making a space as a closed space, in which the processing substrate and the nozzle arrangement face are opposed to each other, to be in a negative pressure state is included. According to a substrate processing device described in Claim 13, in a substrate processing device including: a processing liquid supply mechanism for supplying a processing liquid to a processing substrate; and a substrate holding portion for holding the processing substrate, the processing liquid supply mechanism includes a plurality of nozzle holes which have nozzle ejection ports and are arranged over the processing area, a fence which forms a closed space including at least the processing liquid supply mechanism in processing the processing substrate, a suction pump which is connected to a part of the closed space and makes the closed space to be in a negative pressure state and negative pressure release means for releasing the negative pressure state of the closed space, and the plurality of nozzle ejection ports are arranged so as to be opposed to an area having a projection area substantially corresponding to the processing area.

[0017]

Embodiments

Hereinafter, embodiments of the present invention will be described in detail on the basis of the drawings.

[0018]

(First Embodiment)

Hereinafter, a first embodiment of the present invention will be described in detail by taking wafer developing with reference to FIGS. 1 to 4 as an example.

[0019]

FIG. 1 shows an exemplary form showing the schematic configuration of a substrate processing portion in a substrate developing device according to the present invention, and FIGS. 2 and 3 are enlarged sectional views of the E portion of FIG. 1. In the drawings, reference number 1 indicates a wafer (processing substrate) in which a photosensitive resin film such as a resist is applied on a base film to be processed, reference number 2 indicates a resist (processing area), reference number 3 indicates a developer film (processing liquid film), the reference number 4 indicates a rotatable wafer holder (substrate holding portion) for vacuum-adsorbing and holding the wafer 1, reference number 5 indicates a rotation shaft, reference number 6 indicates a vertical driving mechanism, reference number 7 indicates a nozzle and reference number 8 indicates a plurality of nozzle holes having a fine hole. Reference number 9 indicates a nozzle ejection port arrangement face. A continuous plane is formed between ejection ports of the nozzle ejection port arrangement face 9 and is provided for the purpose of forming a processing liquid film of a developer by surface tension.

[0020]

By the vertical driving mechanism 6, the wafer holder 4 can be vertically moved with respect to the nozzle ejection port arrangement face 9.

[0021]

Reference number 10 indicates a tank for a developer such as an alkaline developer TMAH and is connected to the nozzle 7 by a developer supply system 11. By sending an inert gas such as N_2 into the developer tank 10 through a pressurizing pipe, a developer is supplied to the surface of the nozzle ejection port arrangement face 9 from the nozzle holes 8 via the developer supply system 11. The supply of a developer is stopped by closing a developer supply valve 12. In order to control the stopping operation, an end point determination mechanism 15 determines an end point on the basis of a measurement value of a liquid thickness monitor 14 (beam generating portion 14a, light receiving portion 14b) and a developer quantity control mechanism 16 receiving a determination signal controls the stopping operation of the developer supply valve 12. In addition, a suck back mechanism 17 is attached to the vicinity of the nozzle holes 8 in the

middle of the developer supply system 11 so as not to supply a developer at an unintended timing. A circumferential cup (not shown) is installed around the wafer holder 4 to trap the developer scattering during the rotation of the wafer holder 4.

[0022]

Next, regarding a substrate developing method according to the first embodiment, wafer processing (one wafer) taking use of the above-described single substrate developing device as an example will be described by using an example of the processing flow shown in FIG. 4.

[0023]

First, the wafer 1, in which a latent image is formed on a resist through the processes of pre-baking (100 degrees, 90 seconds), exposure and PEB (100 degrees, 90 seconds) after the application of the resist (film thickness 0.3 μm), is placed on the wafer holder 4 [ST 1].

[0024]

Next, a developer is supplied to the surface of the nozzle ejection port arrangement face 9 from the developer tank 10 in the following order [ST 2]. First, a developer is supplied to the nozzle ejection port arrangement face 9 from the plurality of nozzle holes 8 such that the droplets of the developer supplied from the neighboring nozzle holes 8 are connected to each other as shown in FIG. 2 and the developer film 3 having a surface without localized unevenness is thus formed on the surface of the nozzle ejection port arrangement face 9 by surface tension. The film thickness value of the developer film 3 which is measured by the liquid thickness monitor 14 in real time is transmitted to the end point determination mechanism 15 to determine the end point of the supply on the basis of the previously stored film thickness information and the developer supply valve 12 is closed, whereby the supply of the developer is stopped [ST 3]. FIG. 2 shows the enlarged sectional view of the E portion (the portion in which the nozzle and the wafer are opposed to each other) of FIG. 1 when the developer film is formed [ST 3].

[0025]

Next, the wafer holder 4 is lifted by the vertical driving mechanism 6 [ST 4] and the developing is started by bringing the surface of the resist 2 into contact with the developer film 3 [ST 5].

[0026]

Next, the wafer holder 4 is lifted and stopped just before the surface of the resist 2 is brought into contact with the nozzle ejection port arrangement face 9 [ST 6].

[0027]

From steps ST5 to ST6, the developer is supplied to the entire surface of the processing area without delay.

[0028]

Next, the wafer holder 4 is gradually lowered and a desired quantity of a developer is refilled from the nozzle holes 8 [ST7: second liquid film-forming process]. In addition, the lowering of the wafer holder is stopped at the time point at which a clearance Gr corresponding to the desired quantity of a developer is obtained [ST 8]. FIG. 3 shows an enlarged sectional view of the E portion (the portion in which the nozzle and the wafer are opposed to each other) of FIG. 1 in ST 8. Herein, a representative value of the desired quantity of a developer is defined as the Gr at the end of the nozzle.

[0029]

Next, developing is carried out in this state. After lowering the wafer holder 4 [ST 9] and the elapse of 60 seconds since the start of developing [ST 5], a rinsing liquid is supplied by a rinse nozzle (not shown) and the developing is stopped.

[0030]

After that, the liquid is dried by spin-drying which is performed by rapidly rotating the wafer holder 4. In a post-baking unit (not shown), post-baking (130 degrees, 90 seconds) is performed and thus the formation of a resist pattern is completed.

[0031]

According to the substrate processing device and substrate processing method of the first embodiment, the following problems can be improved at the same time. That is, since the developer film 3 without localized unevenness is formed on the surface of the nozzle 7 by using the surface tension of a developer [ST2, ST3] and then is brought into contact with the surface of the resist 2 [ST 5], the fine air-bubbles 32 shown in FIGS. 11 and 12 are not generated even if there are some cases in which air is introduced by the surface of the developer film 3 and the surface of the resist 2. The air-bubbles which are generated due to the introduction of air by the surface of the developer film 3 and the surface of the resist 2 in this embodiment are large and float on the developer film due to buoyancy, and thus a localized change in finished dimensions and the generation of a pattern defect can be avoided. Since the air-bubbles 32 which are shown in FIGS. 11 and 12 in the conventional techniques are fine, the buoyancy thereof is small and the bubbles remain on the wafer. Accordingly, they cause a localized change in the finished dimensions and a pattern defect. Further, since the surfaces are brought into contact with each other, the surface of the resist 2 can be brought into contact with the developer film 3 without a delay in a static state and thus the problem of a difference in developing time depending on the position in the wafer surface can be solved.

[0032]

The above-described effects can be obtained after preventing the problems of the shock at the time of collision of a developer and the developer consumption quantity.
[0033]

In the above-described processing flow based on FIG. 4, a developer is supplied by the static contact of the surface of the resist 2 and the developer film 3. However, it is also possible that the developer film 3 be formed on the surface of the nozzle ejection port arrangement face 9 and then an inert gas be supplied from an inert gas supply mechanism 18 shown in FIG. 1 to the nozzle holes 8 to drop the developer film 3 onto the resist 2 to thereby start developing.
[0034]

(Second Embodiment)

A second embodiment of the present invention will be described by taking wafer developing with reference to FIG. 5 as an example. The same members or constituent elements as those in the first embodiment are denoted by the same reference numbers.
[0035]

FIG. 5 is a partial view of an exemplary form showing the schematic configuration of a substrate processing portion in a substrate developing device according to the present invention, and the driving systems and supply systems shown in FIG. 1 are omitted therein. The structural difference with the first embodiment is that the surface of the nozzle ejection port arrangement face 9 is shaped such that the surface position thereof gradually rises from a center C to a peripheral portion P. That is, the surface of the nozzle ejection port arrangement face becomes convex and is rotationally symmetrical with respect to the vertical axis at the center C. A difference in the surface position between the center C and the peripheral portion P is preferably in the range of tens of μm to hundreds of μm in the case of a developer.
[0036]

A substrate developing method according to the second embodiment is as follows.
[0037]

First, the wafer 1, in which a latent image is formed on a resist through the processes of pre-baking (100 degrees, 90 seconds), exposure and PEB (100 degrees, 90 seconds) after the application of the resist (film thickness 0.3 μm), is placed on the wafer holder 4.
[0038]

Next, a developer is supplied to the surface of the resist 2 from the plurality of nozzle holes 8.
[0039]

Next, developing is carried out in this state. After the elapse of 60 seconds since the start of developing, a rinsing liquid is supplied by a rinse nozzle (not shown) and the developing is stopped.

[0040]

After that, the liquid is dried by spin-drying which is performed by rapidly rotating the wafer holder 4. In a post-baking unit (not shown), post-baking (130 degrees, 90 seconds) is performed and thus the formation of a resist pattern is completed.

[0041]

According to the substrate processing device and substrate processing method of the second embodiment, since the nozzle ejection port arrangement face 9 has a convex shape, the contact portion between the supplied developer and the surface of the resist 2 is spatially opened from the wafer center portion toward the wafer peripheral portion. Accordingly, since air in the clearance between the resist 2 and the nozzle 7 is removed, a developer is statically applied to the areas on the resist 2 without delay in a state in which the generation of bubbles between the neighboring nozzle holes shown in FIGS. 11 and 12 is suppressed. Accordingly, the problem of air-bubble generation and the problem of a difference in developing time depending on the position in the wafer surface can be solved.

[0042]

In the above-described processing flow, a developer is directly supplied to the surface of the resist 2 from the nozzle holes as in the conventional developing method. However, it is also possible that the developer film 3 be formed on the surface of the nozzle ejection port arrangement face 9 as in the form shown in FIG. 1 according to the first embodiment and then the surface of the resist 2 and the developer film 3 be statically brought into contact with each other to start developing, and it is also possible that the developer film 3 be formed and then an inert gas be supplied from the inert gas supply mechanism 18 shown in FIG. 1 to drop the developer film 3 onto the resist 2 to thereby start developing.

[0043]

In addition, the above-described second embodiment has a form in which the nozzle ejection port arrangement face 9 has a convex shape and thus an air-bubble removal effect is achieved. However, the present invention is not limited to such an exemplary form and the nozzle ejection port arrangement face may be shaped such that the surface position thereof continuously rises from the center to the peripheral portion along the vertical cross section. In addition, in the above-described example, the nozzle ejection port arrangement face is rotationally symmetrical with respect to the vertical axis at the center C and thus it is bilaterally symmetrical with respect to an arbitrary vertical

cross section as in FIG. 1. However, for example, it need not be a rotation object so as to have the shape of FIG. 1 with respect to a certain vertical cross section passing through the center C. Moreover, relative positions of the arrangement face 9 of the plurality of nozzle ejection ports and the surface of the processing substrate may be disposed at upper and lower positions which are continuously changed with respect to a vertical cross section in at least one direction. That is, when at least a part of the surface is tilted, an air-bubble reduction effect to be described later can be achieved. Another modified example (third embodiment) will be shown as an example.

[0044]

(Third Embodiment)

Next, a third embodiment which is a modified example of the second embodiment will be described by taking wafer developing with reference to FIG. 6 as an example. The same members or constituent elements as those in the first embodiment are denoted by the same reference numbers.

[0045]

FIG. 6 shows an exemplary form showing the schematic configuration of a substrate processing portion in a substrate developing device according to the present invention, and the driving systems and supply systems shown in FIG. 1 are omitted therein. A configuration is made in which the surface of the resist 2 and the nozzle ejection port arrangement face 9 can be disposed so as to be opposed to each other while relatively having a tilt in one direction. In this example, a configuration is made in which the nozzle ejection port arrangement face 9 is flat and a tilt angle adjustment mechanism (leveling mechanism) 31 including a broadband sensor (beam generating portion 31a, light receiving portion 31b) for measuring a tilt angle of the wafer 2 is additionally installed. According to this mechanism, the setting of a fixed angle or temporal adjustment of a tilt angle in accordance with the information can be performed. Without the tilt angle adjustment mechanism 31, a mechanism which is fixed at a certain tilt angle can also be used.

[0046]

In the case in which the substrate developing method of the present invention is applied to the above-described substrate developing device, when performing the same processing flow as in the second embodiment, the tilt angle adjustment mechanism (leveling mechanism) 31 performs adjusting to a certain inclination angle such that the surface of the resist 2 and the surface of the developer film 3 have a relative tilt before the supply process of a developer. According to the substrate processing device and substrate processing method of the third embodiment, a developer is supplied to the surface of the resist 2 in a state in which the surface of the resist 2 and the nozzle ejection

port arrangement face 9 are disposed so as to be opposed to each other while relatively having a tilt in one direction. Accordingly, the contact portion between the supplied developer and the surface of the resist 2 is spatially opened from one end portion on the wafer toward the opposite end portion. Accordingly, since air in the clearance between the resist 2 and the nozzle 7 is removed, the generation of bubbles between the neighboring nozzle holes shown in FIGS. 11 and 12 is suppressed and the developer surface without localized unevenness is formed. Further, a developer is applied by being statically brought into contact with the surface of the resist 2 without delay. Accordingly, the problem of air-bubble generation and the problem of a difference in developing time depending on the position in the wafer surface can be solved.

[0047]

In the above-described processing flow, a developer is directly supplied to the surface of the resist 2 from the nozzle holes as in the conventional developing method. However, it is also possible that the developer film 3 be formed on the surface of the nozzle ejection port arrangement face 9 as in the form shown in FIG. 1 according to the first embodiment and then the surface of the resist 2 and the developer film 3 be statically brought into contact with each other to start developing, and it is also possible that the developer film 3 be formed and then an inert gas be supplied to the nozzle holes 8 from the inert gas supply mechanism 18 shown in FIG. 1 to drop the formed developer film 3 onto the resist 2 to thereby start developing.

[0048]

(Fourth Embodiment)

Next, a fourth embodiment will be described by taking wafer developing with reference to the drawings as an example.

[0049]

FIG. 7 shows an exemplary form showing the schematic configuration of a substrate processing portion in a substrate developing device according to the present invention, and the driving systems and supply systems shown in FIG. 1 are omitted therein. The same members or constituent elements as those in the first embodiment are denoted by the same reference numbers. In the drawings, the reference number 101 indicates a fence which can form a closed space S when performing processing (developing) using the wafer 1 and the nozzle 7, the reference number 102 indicates a liquid-gas combination pump (for suction) and the reference number 103 indicates a liquid-gas combination pump (for ejection). The liquid-gas combination pump 102 is used for suction, but when this is provided with an ejection function, the liquid-gas combination pump 103 may not be provided. The reference numbers 104 and 105 indicate pipes for connecting the pumps to the space S via the fence 101 and the reference

number 106 indicates a control portion for controlling the opening and closing of the pumps and the pipes. Both of the wafer holder 4 and the nozzle 7 can be vertically moved.

[0050]

Next, a substrate developing method according to the fourth embodiment will be described by taking the use of the above-described substrate developing device for example with the use of FIG. 7.

[0051]

First, the wafer 1 in which a latent image is formed on the resist through an exposure process is placed on the wafer holder 4.

[0052]

Next, after the closed space S is formed by the wafer 1, nozzle 7 and fence 101, the space S is made to be in a negative pressure state by a suctioning operation of the liquid-gas combination pump 102 and a developer is applied to the surface of the resist 2 by outputting the developer from the plurality of nozzle holes 8. Accordingly, the problem of air-bubble generation and the problem of a difference in developing time depending on the position in the wafer surface can be solved.

[0053]

In the above-described processing flow, a developer is directly supplied to the surface of the resist 2 from the nozzle holes as in the conventional developing method. However, it is also possible that the developer film 3 be formed on the surface of the nozzle ejection port arrangement face 9 and then the negative pressure state of the space S be maintained to statically bring the surface of the resist 2 and the developer film 3 into contact with each other to thereby start developing, and it is also possible that the developer film 3 be formed and then an inert gas be supplied to the nozzle holes 8 from the inert gas supply mechanism 18 shown in FIG. 1 to drop the formed developer film 3 onto the resist 2 to thereby start developing.

[0054]

At the time point at which a desired quantity of a developer is supplied, the liquid-gas combination pump 102 is stopped and a developing process is performed.

[0055]

Then, the liquid-gas combination pump 103 supplies a liquid and the wafer holder 4 and the nozzle 7 are separated from the fence 101.

[0056]

Here, a liquid is fed from the liquid-gas combination pump 103 in order to release the negative pressure state, but this operation may be performed by the ejection function of the liquid-gas combination pump 102.

[0057]

In addition, in place of the liquid-gas combination pump 103, a compressed air supply system may be connected via a valve and the wafer may be gradually lowered while the valve is opened.

[0058]

According to the substrate developing device and substrate developing method of the fourth embodiment, the nozzle holes are surrounded with the closed space before the liquid processing and this space is made to be in a negative pressure state to supply a developer. Accordingly, air in the clearance between the resist 2 and the nozzle 7 is removed and a developer is statically applied to the areas on the resist 2 without delay in a state in which the generation of bubbles between the neighboring nozzle holes shown in FIGS. 11 and 12 is suppressed.

[0059]

In the fourth embodiment, a developer is applied to the surface of the resist 2 by outputting the developer with a negative pressure. However, the developer can also be output by a combination with another method.

[0060]

(Fifth Embodiment)

Next, a fifth embodiment, which is a modified example of the fourth embodiment ,will be described by taking wafer developing as an example. This modified example is an example to which a combination of the first embodiment and the fourth embodiment is applied. Differences between this and the fourth embodiment are that the space S is formed not via the wafer 1 but only by the fence 101, and that the nozzle 7 is moved over the wafer after the formation of the developer film 3 and then the method of the first embodiment is applied.

[0061]

FIG. 8 and FIG. 1 show an exemplary form of a schematic configuration of a substrate processing portion of a substrate developing device according to the present invention configured as separate units in the drawings. In FIG. 8, the same members or constituent elements as those in the fourth embodiment are denoted by the same reference numbers. The space S is formed by the nozzle 7 and the fence 101, but the other parts of the structure are the same as those in FIG. 7.

[0062]

When the substrate developing method of the present invention is applied to the devices of FIGS. 8 and 1, after the closed space S is formed by the nozzle 7 and the fence 101, a suction operation is performed by the liquid-gas combination pump 102 to make the space S to be in a negative pressure state and a developer is output from the nozzle

holes 8, and thus the droplets of the developer supplied from the neighboring nozzle holes 8 are connected to each other and the developer film 3 having a surface without localized unevenness is thus formed on the surface of the nozzle ejection port arrangement face 9 by surface tension.

[0063]

Next, the negative pressure in the space S is released by supplying a gas from the liquid-gas combination pump 103 and the fence 101 is separated from the wall.

[0064]

Then, the nozzle 7 is moved over the wafer holder of FIG. 1 and the steps [ST4 to ST9] of the first embodiment are performed.

[0065]

According to the substrate developing device and substrate developing method of the fifth embodiment, the nozzle holes are covered with the closed space before the liquid processing and this space is made to be in a negative pressure state. Accordingly, in addition to all the effects of the first embodiment, a more excellent air-bubble removal effect can be achieved. In addition, since the steps [ST1 to ST3] and [ST4 to ST9] can be processed in parallel by the separate units, processing capability is improved.

[0066]

Since the processing flows applied in the first to fifth embodiment are exemplified as reference examples, the continuous processing portions may be processed in parallel and vice versa. In addition, the processes can partially overlap with each other or be reversed. For example, a desired quantity of a developer is refilled from the nozzle holes 8 while the wafer holder 4 is gradually lowered [ST7], but the lowering operation and the supply operation may be continuous processes which do not overlap with each other and may be intermittently alternated.

[0067]

In addition, it is necessary to appropriately optimize the respective flows according to the compatibility between a developer and the resist.

[0068]

The refilling of a developer in the above-described second liquid film forming process [ST7] is performed from the nozzle holes 8. However, a developer may be supplied from the clearance between the nozzle 7 and the wafer 1.

[0069]

Before the step [ST5] in which the surface of the resist 2 and the developer film 3 are brought into contact with each other, pre-processing such as pre-wetting using a liquid or the like having lower developing capability than a developer may be suitably

performed on the surface of the resist 2 in order to increase wettability with the developer.

[0070]

All the plural nozzle holes are arranged at constant pitch intervals on the diameter and on the concentric circles. However, in view of the balance in liquid supply, the nozzle holes can also be arranged such that the density thereof is higher in the peripheral portion than in the center portion.

[0071]

Further, the supply of a developer to the plurality of nozzle holes is performed by one system. However, a plurality of supply lines may be provided.

[0072]

The vertical movement may be carried out by the nozzle 7, not by the wafer holder 4.

[0073]

Controlling the stop of a developer, which is described in the (first embodiment), can also be applied to the above-described other embodiments. In addition, in all of the embodiments, the controlling can also be performed by specifying the time or measurement value criterion with, for example, a flow meter 13, not with the end point determination mechanism 15.

[0074]

The above-described first to fifth embodiments show an example of the application of the present invention to a semiconductor wafer developing process. However, the present invention is not limited to such an exemplary form and can also be applied to other processing liquids.

[0075]

Various changes in design and processes can be made within the scope of the present invention. For example, the fifth embodiment shows an example of the combination of the first embodiment with the aspect of the formation of the developer film 3 by a negative pressure. However, for example, a combination with the second embodiment can also be made.

[0076]

Action

As described above, according to the present invention, the following two problems regarding the liquid processing of a substrate can be solved.

[0077]

That is, the present invention contributes to an improvement in processing accuracy and a decrease of defects of a substrate and achieves high yield by solving the

problem of a localized deterioration in a processing accuracy and the generation of defects resulting from air-bubbles and the problem of a difference in processing time depending on the position in the surface of a processing substrate.

Brief Description of the Drawings

FIG. 1

FIG. 1 is a schematic configuration diagram showing an exemplary form of a substrate developing device according to a first embodiment of the present invention.

FIG. 2

FIG. 2 is an enlarged sectional view of the E portion (the portion in which a nozzle and a wafer are opposed to each other) of FIG. 1 when a developer film according to the first embodiment of the present invention is formed [ST3].

FIG. 3

FIG. 3 is an enlarged sectional view of the E portion (portion in which a nozzle and a wafer are opposed to each other) of FIG. 1 when the lowering of a wafer holder according to the first embodiment of the present invention is stopped [ST8].

FIG. 4

FIG. 4 is a flow chart showing the processing flow according to the first embodiment of the present invention.

FIG. 5

FIG. 5 is a partial schematic configuration diagram showing an exemplary form of a substrate developing device according to a second embodiment of the present invention.

FIG. 6

FIG. 6 is a schematic configuration diagram showing an exemplary form of a substrate developing device according to a third embodiment of the present invention.

FIG. 7

FIG. 7 is a schematic configuration diagram showing an exemplary form of a substrate developing device according to a fourth embodiment of the present invention.

FIG. 8

FIG. 8 is a schematic configuration diagram showing an exemplary form of a substrate developing device according to a fifth embodiment of the present invention.

FIG. 9

FIG. 9 is a schematic configuration diagram (sectional view) showing a conventional substrate developing device.

FIG. 10

FIG. 10 is a schematic configuration diagram (top view) showing the conventional substrate developing device.

FIG. 11

FIG. 11 is an enlarged sectional view of the D portion (portion in which a nozzle and a wafer are opposed to each other) of FIG. 9 in a developer supply process of the conventional substrate developing device.

FIG. 12

FIG. 12 is an enlarged sectional view of the D portion (portion in which a nozzle and a wafer are opposed to each other) of FIG. 9 when the developer supply of the conventional substrate developing device is completed.

Description of Symbols

1: WAFER
2: RESIST (PROCESSING AREA)
3: DEVELOPER FILM (PROCESSING LIQUID FILM)
4: WAFER HOLDER (SUBSTRATE HOLDING PORTION)
5: ROTATION SHAFT
6: VERTICAL DRIVING MECHANISM
7: NOZZLE
8: NOZZLE HOLE
9: NOZZLE EJECTION PORT ARRANGEMENT FACE
10: DEVELOPER TANK
11: DEVELOPER SUPPLY SYSTEM
12: DEVELOPER SUPPLY VALVE
13: FLOW METER
14: LIQUID THICKNESS MONITOR
14a: BEAM GENERATING PORTION
14b: LIGHT RECEIVING PORTION
15: END POINT DETERMINATION MECHANISM
16: DEVELOPER QUANTITY CONTROL MECHANISM
17: SUCK BACK MECHANISM
18: INERT GAS SUPPLY MECHANISM
19: AIR-BUBBLE
31: BROADBAND SENSOR
31a: BEAM GENERATING PORTION
31b: LIGHT RECEIVING PORTION
32: FINE AIR-BUBBLES
101: FENCE
102: LIQUID-GAS COMBINATION PUMP (FOR SUCTION)
103: LIQUID-GAS COMBINATION PUMP (FOR EJECTION)
104, 105: PIPE

106: CONTROL PORTION

FIG. 1

6: VERTICAL DRIVING MECHANISM

10: DEVELOPER

15: END POINT DETERMINATION MECHANISM

16: DEVELOPER QUANTITY CONTROL MECHANISM

18: INERT GAS GENERATING MECHANISM

E PORTION

FIG. 4

DRIVING SYSTEM

DEVELOPER SUPPLY SYSTEM

MONITORING SYSTEM

START

ST1: PLACING WAFER 1 ON WAFER HOLDER 4

ST2: STARTING SUPPLY OF DEVELOPER TO LIQUID LAYER FORMING AREA 9 FROM NOZZLE HOLES 8

STARTING MEASUREMENT OF LIQUID THICKNESS MONITOR 14

DETERMINING END POINT OF SUPPLY OF DEVELOPER BY END DETERMINATION MECHANISM 15

ST3: STOPPING SUPPLY OF DEVELOPER (FORMING DEVELOPER FILM 3)

ST4: STARTING LIFTING OF WAFER HOLDER 4

ST5: BRINING SURFACE OF RESIST 2 INTO CONTACT WITH DEVELOPER FILM 3

START OF DEVELOPING

ST6: STOPPING LIFTING OF WAFER HOLDER 4 JUST BEFORE SURFACE OF RESIST 2 IS BROUGHT INTO CONTACT WITH LIQUID FILM FORMING AREA 9

ST7: STARTING LOWERING OF WAFER HOLDER 4

REFILLING DEVELOPER FROM NOZZLE HOLES 8

ST8: STOPPING LOWERING OF WAFER HOLDER 4 WHEN CLEARANCE IS EQUAL TO GR

ST9: LOWERING WAFER HOLDER 4

ST10: RINSING/DRYING

60 SECONDS

END OF DEVELOPING

END

FIG. 6

31: TILT ANGLE ADJUSTMENT MECHANISM

FIG. 7

DEVELOPER

106: CONTROL PORTION

FIG. 8

10: DEVELOPER

106: CONTROL PORTION